AUTOMATED ANALYSIS OF ZOOPLANKTON SIZE AND TAXONOMIC COMPOSITION

Cabell S. Davis

Biology Department,
Woods Hole Oceanographic Institution,
Woods Hole, MA 02543
508-289-2333, cdavis@whoi.edu

Scott M. Gallager

Biology Department,
Woods Hole Oceanographic Institution,
Woods Hole, MA 02543
508-289-2783, sgallager@whoi.edu

W. Kenneth Stewart

APO&E Department
Woods Hole Oceanographic Institution,
Woods Hole, MA 02543
508-289-2644, kstewart@whoi.edu

Award # N00014-93-1-0602

LONG TERM GOALS

The goal of this project is to develop methods for automated analysis of zooplankton size and taxonomic composition using images from theVideo Plankton Recorder (VPR). The goal is to sort plankton to species or genus level and measure body size in real time at sea. The VPR provides sharply focussed video images of plankton and seston in the size range 100 microns to 5 cm and has an on-board CTD, fluorometer, flowmeter, and transmissometer. Currently the VPR is towed at 0.5-5.0 m/s and has been deployed in shelf and oceanic waters, including extensive survey work on Georges Bank. The VPR has also been deployed on the ROV JASON for individual particle tracking, and a moored profiling system is under development, which will include on-board image processing and satellite telemetry of processed data.

OBJECTIVES

Our four specific objectives are to: 1) use our existing hardware to develop methods for real-time detection (60 fields per second) of in-focus organisms in the video and for storing the images to disk; 2) develop pattern-recognition software for classification of organisms into major taxonomic groupings (copepods, chaetognaths, doliolids, etc.); 3) develop specifications for transferring the software routines to hardware to enable real-

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1997		**00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE
Automated Anlaysis of Zooplankton Size and Taxonomic Composition

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Woods Hole Oceanographic Institution,Department of Biology,Woods Hole,MA,02543

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

time sorting of zooplankton according to major taxa; and 4) to develop a data-analysis and display system for real-time visualization of plankton distributions. Development of the complete image processing/data analysis package enables incorporation into the VPR system for real-time identification of planktonic taxa and visualization of their distributions while at sea.

APPROACH

Our approach for the first objective was to develop software for accurate focus detection and then transfer it to our IT-151 image processor. The approach for the second objective was to develop software for identification and sorting organisms to major taxa. The third objective involved establishing specifications for hardware that operates the identification and sorting software in real-time. The fourth objective was to develop a data analysis system for viewing the spatial patterns at sea in real time.

WORK COMPLETED

We have achieved all objectives of this project and have used the prototype system at sea to identify and visualize planktonic taxa in real time (Davis et al, in draft). This project has involved development of a real-time focus detection system, development of algorithms for feature extraction and identification of planktonic taxa, and development of data visualization software for display of plankton and physical data.

RESULTS

Objective 1: We have developed accurate focus-detection algorithms and implemented them in hardware. Initially this was done using an Imaging Technology Inc. Model 151 (ITI-151) real-time image processor interfaced to a Sun SPARCstation 20, but we have upgraded the system to an ITI Model 150-40 running on a Pentium PC to take advantage of the rapid I/O of the PCI bus. The old system missed in-focus objects and would skip frames due to an I/O bottle neck in the Sparc S-Bus. The new PCI based system is much faster and is capable of extracting all in-focus images. A video source (live camera or tape player) sends a video signal and time code to the ITI 150-40 and to a separate time-code reader connected to the PC serial port. Algorithms were developed for reading field-accurate (60-Hz) time code into the PC and for synchronizing the ITI 150-40 pipeline processor for real-time region-of-interest (ROI) selection. In-focus ROIs then are stored on disk as TIF files..

Our capability for real-time focus detection allows for rapid automated culling of blank and out-of-focus images, reducing manual video processing by a factor of more than 50. We have used the focus-detection system coupled to a point-and-click user interface for rapid analysis of zooplankton distributions at sea (Davis et al., 1996). We used this method on our Georges Bank GLOBEC cruises to observe 2- and 3-D plankton distributions (Gallager et al., 1996; Benfield et al., 1996; Norrbin et al., 1996; Benfield et al., submitted; Ashjian et al., in draft; Davis et al., in prep; Gallager et al., in prep)

Objective 2: In addition to focus detection, we also have developed feature-extraction and pattern-analysis algorithms for classification according to taxonomy and size. Our new algorithms have classification accuracy at about 90% for several plankton taxa. Our research efforts have focused on: 1) gray-scale morphology and granulometric feature extraction; 2) textural feature extraction; and 3) feature orthogonality and optimal discrimination.

1) For Binarization, Dr. Luc Vincent has developed a new approach to using a global-connectivity histogram of the image; histogram plateaus indicate which threshold values are most stable. Granulometric algorithms were improved, especially with respect to scale, filtering, and normalization; classification results indicate good discrimination for plankton images. A novel "geodesic radial function," the ordered set of values of the propagation function along the boundary of the binarized plankton mask is an important feature. The function captures the size and elongation of the organism, its extremities and their sharpness, and overall smoothness.

2) Postdoctoral Investigator Xiaoou Tang has developed a recursive segmentation scheme inspired by unsupervised clustering; the technique offers speed, simplicity, and performance comparable with the global-connectivity histogram. Next, a set of geometrical features (e.g., area, perimeter, shape factor, rotation- and scale-invariant moments) are computed from the binary segmented image. Other textural features (e.g., run length, co-occurrence, gray-level difference, wavelet, power spectrum, fractal dimension) are also extracted from the original gray-scale images. These and other feature vectors were developed, including the geodesic radial function and a boundary shape descriptor, and incorporated into a robust feature set.

3) With very large feature vectors much information is redundant, demanding great computational power and also showing poor results. An important step is the decorrelation and feature selection. Tang developed a new dominant principal component analysis approach on the combined large feature vectors formed by various features described above. Then the selected dominate features are sorted according to their discrimination power by the Bhattacharyya distance measure. Dramatic improvement of the classification accuracy is achieved by only using a simple statistical classifier.

Objective 3: Once the training sets and related software were established, the focus, sizing, and identification algorithms allow completely automated analysis of VPR images. We have used the feature extraction and classification algorithms on our workstations to achieve real-time processing and classification of the VPR images as they are acquired at sea.

IMPACT

The new sampline capability developed in this project will provide new insights into the processes controlling plankton distributions and thus sound and light transmission in the sea. The ability to visualize the distribution of planktonic taxa (and size structure) at sea in real time allow for a better understandin of pelagic biology. No longer will we be probing in the dark, only able to analyze the point source data once samples have been processed in the laboratory months or years later. The dynamical nature of the pelagic environment necessitates the use of tools which can provide rapid visualizations of plankton distributions together with physical properties of the water. The prototype system we have developed provides this capability.

TRANSITIONS

The real-time sampling system can be used in any studies in which it is desirable to measure plankton abundance including sound and light scattering studies and ecological studies of environmental quality and fisheries ecology.

RELATED PROJECTS

The video processing procedures we have developed are closely coupled to our NSF/NOAA funded research on Georges Bank (GLOBEC) and our NSF-funded development of a vertically profiling VPR.

REFERENCES

Davis, C. S., S. M. Gallager, X. Tang, and C. J. Ashjian. Real-time visualization of taxa-specific plankton distributions. (in draft)

Ashjian, C. A., C. S. Davis, S. M. Gallager, and P. Alatalo. Seasonal evolution of plankton and particle distributions across Georges Bank as measured using the Video Plankton Recorder. (in draft)

Benfield, M. C., P. H. Wiebe, T. K. Stanton, C. S. Davis, S. M. Gallager, and C. H. Green. Solving the inverse problem by combining video and acoustic data. submitted.

Gallager, S. M., C. S. Davis, and H. Yamazaki. In situ three-dimensional observations of plankton swimming behaviors and microturblence using the Video Plankton Recorder on the ROV JASON in a dense layer of {\it Chaetoceros socialis} colonies. (in prep)

Davis, C. S., S. M. Gallager, and P. Alatalo. Micro-meso scale distributions of Georges Bank plankton during vernal stratification and ring entrainment: association of {\it Calanus finmarchicus} and other plankton with a dense layer of large algal colonies {\it Chaetoceros socialis}. (in prep)

Sieracki, M., D. Gifford, S. M. Gallager, and C. S. Davis. Observations on a dense patch of the diatom, Chaetoceros socialis, on the southern flank of Georges Bank: Distribution, colony structure and grazing losses. Oceanogr., in press.